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*Keywords: microcontroller, incubator, temperature sensor, relay driver, relay, heater and buzzer.*

GJSFR-D Classification : *FOR Code: 830309*

DESIGNANDDEVELOPMENTOFAMICROCONTROLLERBASEDEGGINCUBATORFORSMALLSCALEPOULTRYPRODUCTION

*Strictly as per the compliance and regulations of :*

# Design and Development of a Microcontroller based Egg Incubator for Small Scale Poultry Production

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## I. Introduction

Poultry is an important part of Ethiopian diet. To date however, the supply of poultry products in the country is limited owing to low production potential of small poultry farmers. This is evidenced by the high cost of poultry products in the area such as dressed and processed chicken meat. The absence of local equipment like an incubator suitable for small scale poultry production in the countryside is one of the challenges facing the poultry industry.

In Ethiopia chickens are the most widespread and almost every rural family owns chickens, which provide a valuable source of family protein and income [1]. The country has diverse agro-climatic conditions that are favourable for the production of many different kinds of crops, providing a wide range of ingredients for feeds suitable for poultry and livestock. Making use of these resources to complement the scavenging resource base promises a considerable potential for success [2]. The total population of chicken in Ethiopia is about 50.38 million comprising cocks, cockerels, pullets, laying hens, non-laying hens and chicks of which 96.9%, 54% and 2.56% were reported to be indigenous, hybrid and exotic chicken breeds, respectively [8].

The agriculture sector employs 80-85% of the population and contributes 40% to the GDP [4]. Livestock production as a component of agriculture constitutes 40% of the agricultural output and contributed 13-16% of the total GDP [5, 6]. It was reported further that 99% of the total 56.5 million estimated chickens are contributed by village poultry production [7].

This study was aimed to design and develop an egg incubator appropriate for the socio-economic setting of the country, where small rural farmers cannot afford the costly imported equipment. With this locally available technology, it is expected that it would contribute much to the development of the poultry industry in developing countries and Ethiopia in particular and consequently to the alleviation of rural poverty. This research also supports the mission of the Science, Technology and Innovation Policy of Ethiopia "to create a technology transfer framework that enables the building of national capabilities in technological learning, adaptation and utilization through searching, selecting and importing effective foreign technologies in manufacturing and service providing enterprise" [3].

## II. Materials & Methods

### *a) Hardware and Software Components of Microcontroller Base Egg incubator*

The block diagram of the microcontroller base egg incubator is shown in figure 1. The microcontroller is the heart of the control circuit. The temperature sensor sends the actual temperature inside the incubator to microcontroller. The microcontroller turns on and turns off the heater on the required temperature. The heater driver and fan driver are used to interface the low voltage output coming from the microcontroller to high voltage as required by the heater. A DC motor is used to turn the eggs at specified time. The motor driver is connected to the microcontroller to control the turning of the eggs. The fan turns on and off as specified by the

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microcontroller. The buzzer is used to make sound alarm when the incubation period is over.

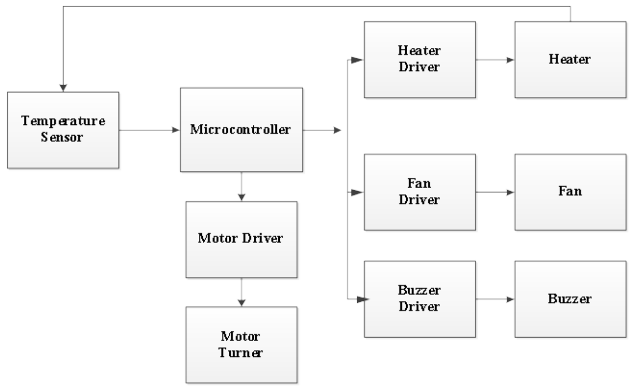


*Figure 1 :* Block diagram ofthe microcontroller base egg incubator

*b) Temperature Sensor and Microcontroller*

The LM35 temperature sensor was used in the circuit. A PIC16F877A was also used as the main controller of the system. The circuit of the temperature and microcontroller is shown in figure 2.

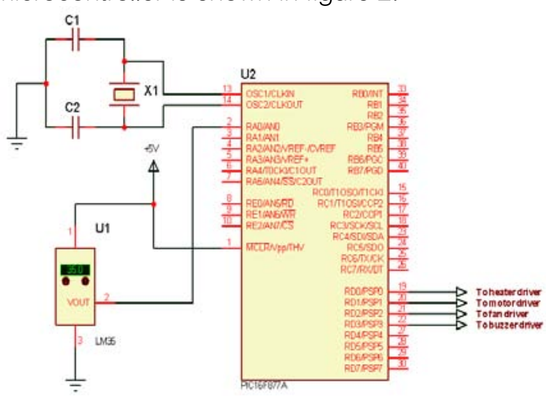


*Figure 2 :* The microcontroller and temperature sensor circuit

Based on the microchip recommendation from the manufacturer of PIC16F877A, a 4MHz crystal oscillator and a 22pF ceramic capacitor were used as the clock timing of the microcontroller. The Pin 2 of the LM35 temperature sensor was connected to analog input of PIC16F877A, while pin 1 and pin 3 were connected to +5V and ground of the power supply, respectively. The heater driver, motor driver, fan driver and the buzzer driver were connected to PORTD of the microcontroller as shown in figure 2. From the datasheet of LM35 temperature sensor, it can sense -55°C to 150°C with a linear scale factor of 10mV/°C. The egg incubator was set to operate at temperature range of 37°C to 38°C. The LM35 temperature sensor was used in this project.

*c) Motor Driver and Motor Turner*

A common emitter transistor configuration circuit was used as driver to the motor. The low speed 12V DC motor was used for automatic egg turner of the incubator. A 10 RPM angular speed of the motor was used so that the eggs will not be broken when the turner operates. The turner motor operates every 6 hours for 30 seconds. The time of the turner operation was tested by varying the time of operation of the turner motor using chicken eggs. The turner was set to activate every 6 hour for 30 seconds. This corresponds to the recommended turning frequency of four times a day for chicken eggs during incubation period.

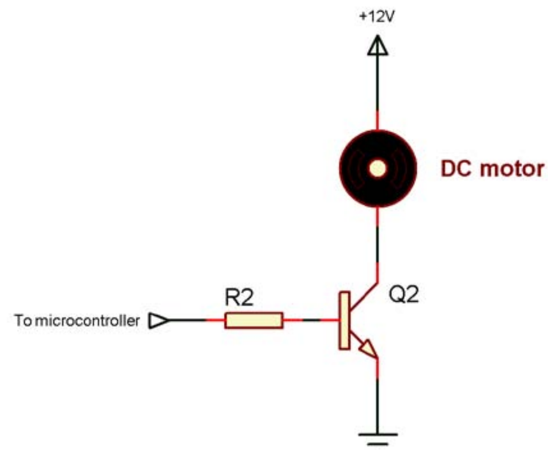


*Figure 3 :* The Turner Motor and Driver Circuit

The DC motor has a current rating of 1.5 amperes. The transistor needs a collector maximum current more than the load current which is the motor in this case. The 2N3055 NPN transistor was used in this circuit. From the datasheet, it has a 15 amperes collector maximum current rating. The value of resistor was computed as follows.

From the equation:

$$Ib = \frac{Ic}{\beta}$$

Where Ic is the current coming from the motor, $\beta = 100$ and Ib is the base current.

Thus;

$$Ib = 15 \text{ mA}$$

The current Ib was used to determine the value of the base resistor. Using Kirchhoff's voltage law the value of resistor;

$$R = 286.7\ \Omega$$

For actual resistance value, applying the safety factor of 80% was about 470 $\Omega$. The resistor used in the actual circuit was about 500 $\Omega$. The base resistor was directly connected to pin 20 of the microcontroller.

*d) Fan Driver and Fan*

A small DC computer fan was used in the incubator. And the small transistor driver was used to control the fan with the microcontroller. Figure 4 shows the circuit diagram of the fan driver and the fan.

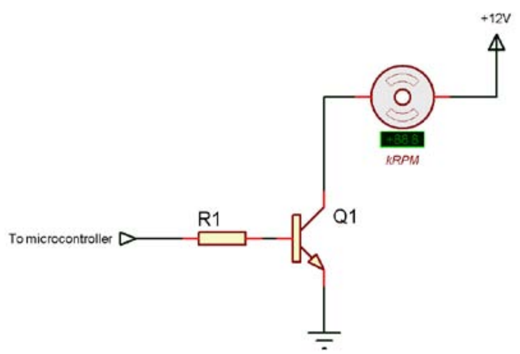


*Figure 4 :* The fan driver and fan circuit

The transistor used in the circuit was 9013 general purpose NPN transistor. The maximum collector current of this transistor was about 1000 mA. The fan maximum current was around 500 mA. The value of the resistor can be computed using the same procedure with the motor driver circuit. The resistor was directly connected to pin 21 of the microcontroller.

*e) Buzzer Driver and Buzzer*

A small 12volts DC buzzer was used to generate sound when the incubation period has elapsed. The buzzer driver and the buzzer connection are shown in figure 5.

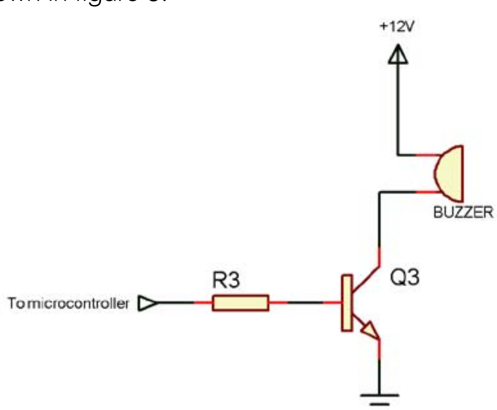


*Figure 5 :* The buzzer driver and buzzer circuit

The 9013 general purpose NPN transistor was used to drive the buzzer. The buzzer has a 150 mA current. The resistor value was computed in the same way with the motor driver circuit. The β of the transistor based on the 9013 datasheet was 100. The resistor was directly connected to pin 22 of the microcontroller.

*f) Heater Driver*

The heater driver circuit consists of a relay and transistor as shown in figure 6. The transistor base resistor was computed as follows.

From the equation,

$$\text{Ib} = \frac{\text{Ic}}{\beta}$$

Where:

Ic = Relay coil current flowing to the collector current

Applying Ohm's Law,

$$\text{Current of Relay Coil} = \frac{\text{Coil Voltage}}{\text{Coil Resistance}}$$

Based on the resistance test, the coil resistance was found out to be 100 ohms.

Thus, relaycoil current is equal to 120 mA and Ib = 1.2 mA

$$\text{R4} = 3.6\ \text{K}\Omega$$

The resistor was directly connected to pin 19 of the microcontroller. The diode connected to the relay coil serves as the flywheel diode. It protects the transistor during the turning off of transistor. The diode used in the circuit was 1N4004. This diode has a peak inverse voltage of 300 volts and the current rating of 1000 mA.

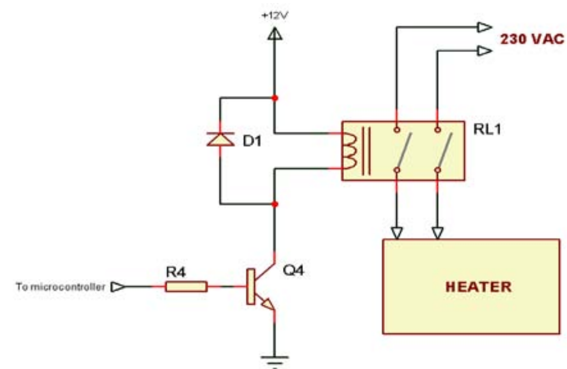


*Figure 6 :* The heater driver circuit

*g) Heater*

The heating system of the incubator plays an important role in maintaining the required temperature inside the incubator. The incubator operates from 37°C to 38°C. The incubator box produces conductive heat transfer from outside and inside environment. The conductive heat transfer was computed using the equation.

$$q = kAdt/s$$

where:

q = heat transfer
A = heat transfer area
k = thermal conductivity constant of the material
dt = Temperature gradient difference in the material
s = material thickness

The material used in this incubator has a thermal conductivity constant of 0.11 based from the experiment conducted by Oak Ridge National Laboratory.

The incubator box inside dimensions are shown in figure 7.

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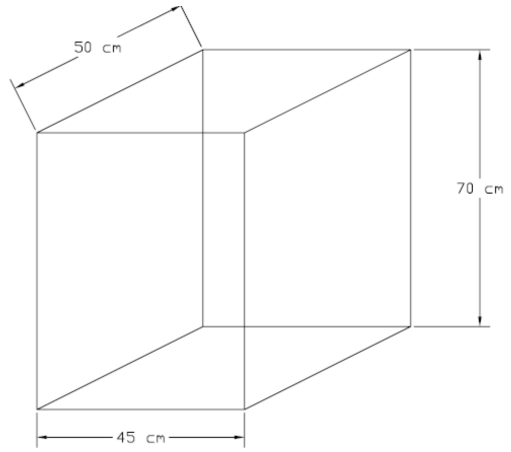


*Figure 7 :* The inside dimensions of incubator

Applying the heat conductive transfer equation, the heat transfer was found to be 200w for the total surface area in order to maintain the required temperature inside the incubator. The infiltration loss was assumed to be 30w. The incubator uses incandescent bulbs as heaters. According to the National Science Foundation, 90% of the total power of incandescent bulb turns into heat energy. To maintain an even distribution of heat inside the incubator, the incandescent bulbs were evenly distributed as shown in figure 8.

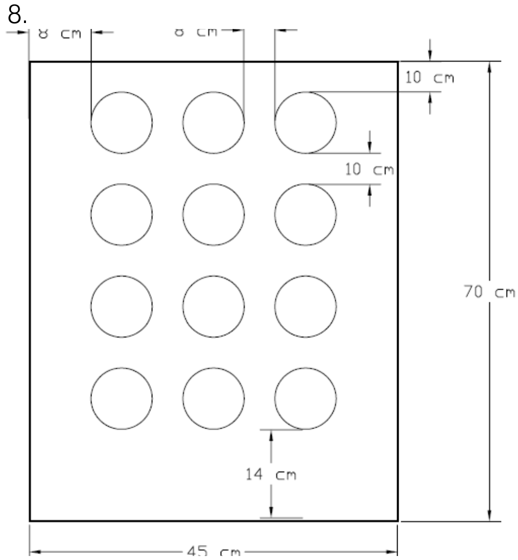


*Figure 8 :* The bulb arrangement at the right side of the box

The 10w incandescent bulbs were used in the incubator. The total number of 10w bulb used was 21 pieces since only 9w was converted to heat in order to achieve 200w of heat energy. The other 12 bulbs were placed in the side of the incubator, while the other 9 bulbs were placed at the top of the incubator. The distances of each bulb were evenly distributed.

*h) Power Supply*

The controller requires a 12 and 5 volts DC. The power supply circuit of the incubator is shown in figure 9. Based on the actual test of the total current of the controller circuit, it was found out to be 2.5 amperes. The transformer used in the circuit was a 3 amperes center tap with an output voltage of 12 volts.

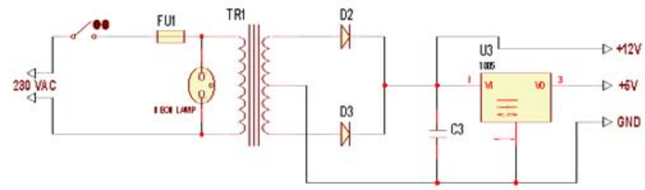


*Figure 9 :* The power supply circuit

The primary side of the transformer consists of a fuse and a switch. The neon lamp was used as power indicator of the power supply. The fuse in the primary side of the transformer was computed using the formula,

$$\text{Fuse Rating} = \frac{\text{Secondary Current}}{\text{Transformation Ratio}}$$

Where secondary current is the total current consumed by the controller and the driver circuit.

Thus;

Transformation ratio = 230 :12
Transformation ratio is equal to 19.
Computed Fuse Rating = 0.157 A

The actual value of fuse rating applying the safety factor is about 0.5 amperes.

The rectifier diode used in the circuit was 1N5404. It has a peak inverse voltage of 400 volts and a maximum current rating of 4 amperes. The filter capacitor was computed with a resulting value of 2200 uF for minimal ripple factor. The LM7805 regulator was used in the power supply. The regulator has a 5 volts output that was used to power-up the microcontroller circuit. The power supply has also a 12 volts output that can be used for motors, relay and buzzer.

*i) Embedded Program*

The microcontroller needs an embedded instruction in order to work at the specified required output. The flowchart of the system is shown in figure 10.

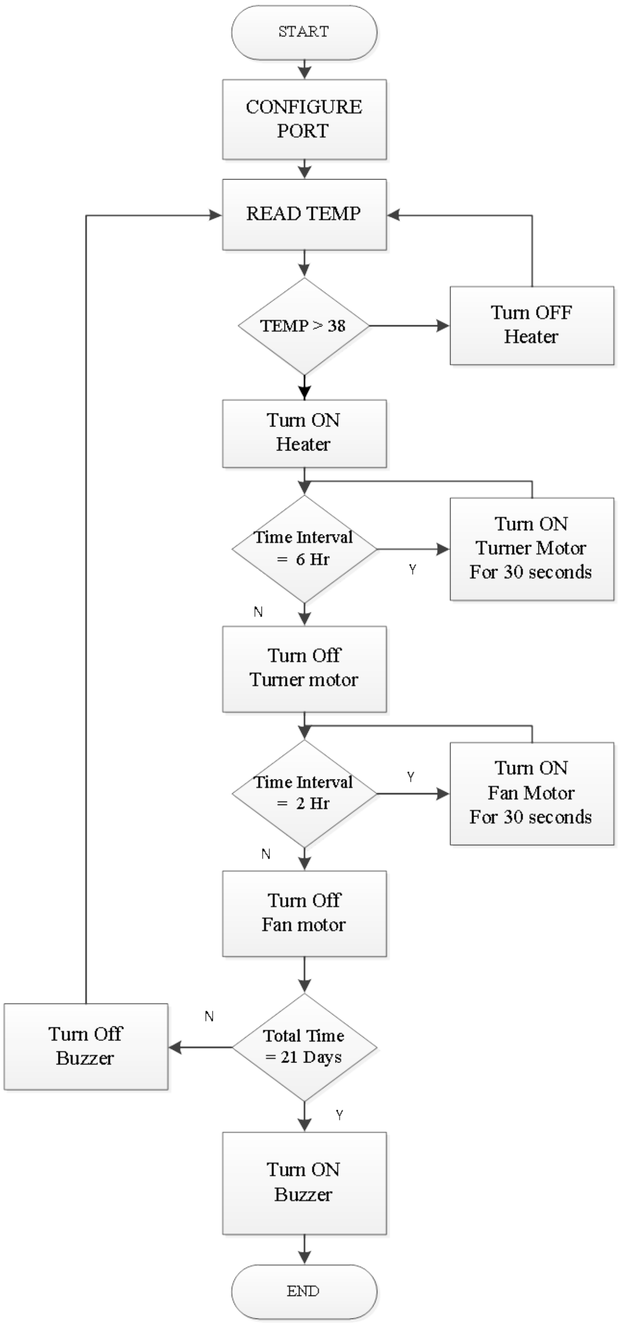


*Figure 10 :* The system flowchart

In figure 10, the different ports of microcontroller were initialized and configured based on the hardware connection. The sensor reads the temperature and sends it to the analog input of microcontroller. The microcontroller compares the temperature based on the requirement of egg incubator. If the temperature is greater than 38°C the heater will be turned off otherwise it is on. The microcontroller continues counting the time interval and total time accumulated. If the time interval is 1 hour, the fan will turn on for 30 seconds and turns off thereafter. If the time interval is about 6 hours the turner motor will turn on in order to rotate the egg for about 30 seconds. If the total accumulated time is 21 days equivalent the buzzer will generate a sound to remind that the incubation period has ended. The program was written in MikroC.

*j) Performance Evaluation of the Prototype Egg Incubator*

The prototype egg incubator in operation is shown in Figure 11. Performance evaluation of the egg incubator was made by loading the incubator with 20 pieces of chicken eggs which were purchased from one of the commercial poultry farms in Oromia region. The eggs came from a breeder flock and were assumed to be fertile eggs.

Before loading the eggs, the pan in the incubator was filled with tap water to maintain the required internal humidity for egg incubation to prevent them from drying up. Then the eggs were loaded on the tray before the power supply was turned on. Candling of eggs was done after seven days of incubation to identify the fertile from infertile eggs using an improvised candler. The power interruptions during the entire incubation period were also noted.

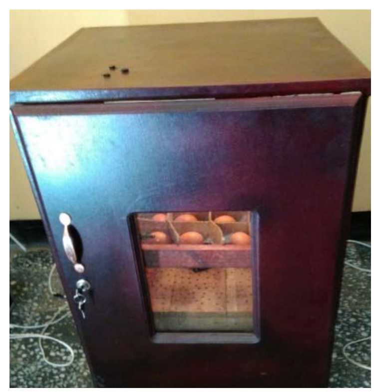

*Figure 11 :* The prototype microcontroller base egg incubator used in this study

## III. Results and Discussion

*a) Performance of the Prototype Egg Incubator*

The prototype microcontroller base egg incubator was found to operate as designed. The turner automatically turns the eggs every 6 hours for 30 seconds or 4 times a day. The fan which is designed to circulate the air inside the incubator also performed as designed. The incubation temperature of 38°C was also achieved during the test. During the incubation period, the power supply interruptions of 2 to 6 hours per day occurred in the area.

*b) Fertility and Hatchability*

It was found that only 11 eggs out of 20 were fertile corresponding to 55% fertility. Of these 11 fertile eggs, only 3 were hatched after the incubation period of 24 days. Two eggs were hatched after 21 days of incubation (Figure 12) and one after 24 days. The percent hatchability therefore was only 3/11 or about 27%.

*Figure 12 :* Hatched eggs after 21 days of incubation

It has been reported that during power outage, embryos can survived at temperatures below 32°C for up to 18hours, and frequent power outage will delay hatching by a few days and decrease the hatchability to 40-50 percent [9]. The daily power interruptions of 2 to 6 hours a day during the incubation period could be the main reason for the low hatchability and delay in hatching of the eggs. Figure 13 shows the appearance of an embryo after 21 days of incubation period showing a delayed development because of frequent power outage in Adama area during the testing period.

*Figure 13 :* Appearance of under develop embryo after 21 days of incubation resulting from frequent power outage in the area

## IV. Conclusion

The four factors of major importance in incubating eggs artificially includes temperature, humidity, ventilation and turning. Of these factors, temperature is the most critical. Extensive research has shown that the optimum poultry incubator temperature is (38°C) when relative humidity is 60 per cent. The prototype microcontroller base incubator is a forced-air incubator which has a built in fan to circulate the air that maintains humidity and temperature at constant level. Results revealed that the prototype microcontroller based incubator functioned according to the designed operating temperature, humidity, and frequency of turning the eggs during the performance test. A stable power supply is needed for the optimal hatching performance of the incubator.

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